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Intelligent Buildings: Considerations for its Design using Multiagent Systems

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Abstract **- In the design phase of Intelligent Buildings, it is essential to manage many services and facilities, to do this, multi-agent systems are a good tool to manage them. This article addresses fundamental aspects of multi-agent systems, oriented to their integration into the design and construction of intelligent buildings. Sensors, control and actuators must be integrated in the initial stages of the construction design to harmonize the different functionalities that are required of an Intelligent Building. In the article, once the concept of Intelligent Building was established, the complexity of its architectural design, makes it convenient to have a structure of procedures that serves as a guide for its integrated design, this has been the central objective of the article, multiagent systems are instrument of design and implementation that allow to compose the different subsystems of control that characterize the Intelligent Buildings. The article provides a review of different approaches to multiagent systems applied to building construction, the basic elements of multiagent systems and the set of their systems to be considered in the early stages of designing an Intelligent Building.**

Keywords – Architecture, Intelligent Building, Multiagent Systems

I. INTRODUCTION

The multiagent systems (MAS) constitute a field of research that compose a wide set of applications within Intelligent Buildings, their construction [1], sensor and control of buildings [2], [3], maintenance of Intelligent Buildings [4]. A modern approach to Architectural Construction involves considering MAS as elements linked to the architectural design of buildings [5]. In this sense, a multidisciplinary approach to architectural design is essential [6], the Building Information Models [7] supplemented with the MASs constitute powerful systems of holistic design of buildings.

This article addresses the fundamental aspects of multiagent systems, oriented to their integration into the design and construction of Intelligent Buildings. Sensors, actuators and control systems must be integrated in the initial stages of the design, in order to harmonize the different functionalities that are required of an Intelligent Building [8].

I. INTELLIGENT BUILDINGS

The Intelligent Building Index (IBI) manual has been developed by the Asian Institute of Intelligent Buildings (AIIB). The definition of Intelligent Building adopted by this association is: "An Intelligent Building is designed and constructed based on an appropriate selection of Quality Environment Modules to meet the User's requirements by mapping with the appropriate building facilities to achieve the Long-Term Building Value"

The provisions that influences the condition of Intelligent Building: (H Chow & T Leung, 2005) are established from the following slopes:

• Green Building, this integrates the friendly use of environmentally components in a building, such as energy consumption by ventilation, lighting, air conditioning, etc.

• Layout of the Space, includes groups of elements of Architectural Design, Parking and Transportation, Interior Architectural Design Flexibility.

• Comfort, it consists of several groups of elements of Architectural Design, Lifts Systems, Washbasins and Provisions of Appliances, Thermal Comfort, Ventilation and Air Conditioning, Lighting, Access, Acoustics, Color, Entertainment Facilities, etc.

• Efficiency of Work (own office buildings and services), includes several groups of Architectural Design elements, Lifts and Stairs, Appliances and Restrooms, Thermal Comfort, Lighting, High Technology, Signage and Directory, Parking and Transportation, Installations for Buildings, etc.

• Cultural Elements. It is considered as the "soft" side of an intelligent building. They include Entertainment Facilities, Privacy Requirements, Colors, Interior Decorating, Food and Beverage Control, Exterior Landscape and View, Interior Plants, Religious Facilitation, Culture Based Interior Design, Promotion Activity, etc.

• High Technology Image. It has been interpreted for many years as the only provision and/or criterion of an intelligent building. The groups of elements are Broadband Internet, Electrical Services, Office Automation, Electronic Installations, Intelligent Artificial Control, Web Page, Direct Lines, Telephone Arrangements, Fiber Optic Network, Building Services Automation, Mobile Phone Coverage, Installations Advanced Parking, etc.

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• Security and Structure. It consists of several important parameter elements in a smart building. Elements include earthquake monitoring, structural monitoring, terrorist attack precaution plan, fire protection, electrical safety, lift reliability, public notices, escape plan, essential electrical power, preventive maintenance of building systems, indoor air quality, security management system, risk management, safety and crowd control, etc.

• Building Management. Including Operation and Maintenance of Construction Services, High Technology, Security and Surveillance, Controls, Management Planning, Water Supply and Drainage, Environmental Protection, etc. In general, this section would include the cost of the life cycle of a building.

• Healthy Building. It is particularly interesting in the evaluation of residential buildings. The groups of elements include, drinking water and washing system, drainage, toilet, parking and elevator ventilation, smell, cleaning, waste management, pest control, filtration in swimming pools, etc.

All these elements have different influence in the building depending on its use, offices of work, residential, commercial, etc. In any of them, the increasing weight and set of these elements contribute to the consideration of Intelligent Building. At the design level, we can consider two types of elements, those that make up the classic architectural design and those that make up the architectural design based on the information management that is generated in the building.

In the following of the article we are going to see the multiagent systems to use them for the architectural design based on the information management that is generated in the building.

II. MULTIAGENT SYSTEMS

In the field of intelligent building design, we must have mechanisms to integrate sensors, actuators, different automatic control systems and information capture. MultiAgent Systems (MAS) form a community of interdependent elements that act individually. From the moment that a group of elements, in this case agents, assume to act in group forming systems, the capacity to negotiate and to coordinate different tasks is necessary.

In many cases the use of individual agents is not just as suitable for all situations that occur in practice. Solving a problem using an individual agent causes major constraints. An individual agent requires an enormous amount of knowledge to solve complex problems. In the worst case, the problem can be so complex that an agent cannot find a useful solution. Even when the individual agent can solve a problem, it always presents a bottleneck in terms of speed, reliability, flexibility and modularity. Multi-agent systems offer a method to avoid the problematic situations described. In a multi-agent system, several independent autonomous agents are active [9]. Each of these agents is dedicated to their own objectives and only contacts the other agents to obtain information, or to contribute to a coordinated solution of a general problem. In both situations, each individual agent has a specific task for which it is adequate and whose solution does not exceed its capabilities. This allows for the processing of complex problems.

Multi-agent systems provide a great advantage: they allow the integration of existing agents into a large system. Therefore, solving a problem does not require the design and development of a new specialized agent, instead, the knowledge of existing agents can be used by combining them into a multi-agent system and allowing them to work together to solve the problem.

III. INTERACTION BETWEEN AGENTS

In a multi-agent system, an agent must anticipate the actions of the other agents in their own planning task and how it can influence the actions of other agents in benefit of their own objectives. The effects of the actions of other agents on our agent may be favorable, neutral or detrimental to our agent's objectives. To influence what another agent will do we will need methods for an agent to communicate with another agent.

The simplest kind of agent interaction would be the one in which our agent reacts to the effects of the environment generated by other agents as they occur and perceive them. These are reactive agents. In this case, there would be no explicit communication between them, nor would we need models of the other agents. If our agent has to take into account the activity of the other agents, you will need to have models that you can use to predict how these will behave and use them when building your own plans. The model of the agent, along with the mechanism to use it and select the actions, is called cognitive structure. Often, the cognitive structure also includes the agent's goals and intentions [10]. All this we will deal with in more detail in section 3 when talking about the architectures of agents.

Some basic characteristics of multi-agent systems are: (1) Each agent has a limited view of the state of the world, ie, has incomplete information. (2) There is no global control, the control of the system is distributed. (3) The information is decentralized. (4) The computation is asynchronous.

In a multi-agent system, we can find in situations of cooperation or competition. In the first case, the agents will have to be able to combine their efforts, usually to obtain solutions of problems that the agent itself is not able to find (CMAS Cooperative Multiagent Systems). On the other hand, from the moment we have agents who fulfill our orders, other people will have agents who will fulfill theirs. And while our agents want the best for us, those of others will also try their best for their owners (SMAS Self-Interested Multiagent Systems). In the latter type of systems negotiation strategies play a preponderant role that allow to resolve conflicts, assign tasks and take.

Interaction protocols (AIP, "Agent Interaction Protocols") are often quite complex. An inter-agent interaction protocol describes a communication pattern as an

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allowed sequence of messages between agents and restrictions on the content of such messages. To help us we can represent them through AUML (Agent UML - "Agent Unified Modeling Language") [11]. It is an extension of UML to deal with agents.

There are different methods of communication. The invocation of the procedure of an agent by another agent represents the simplest case. However, only simple communication methods can be implemented using procedure calls. For this reason, procedure calls are not considered a method of communication.

Communication methods can be differentiated into blackboard systems and message dialog systems, shown in Fig. 1, Fig. 2 and Fig. 3.

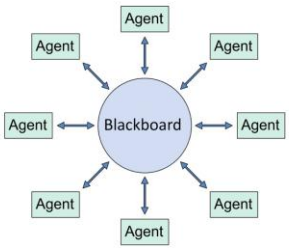

Figure 1. Structure of a Blackboard Communication System

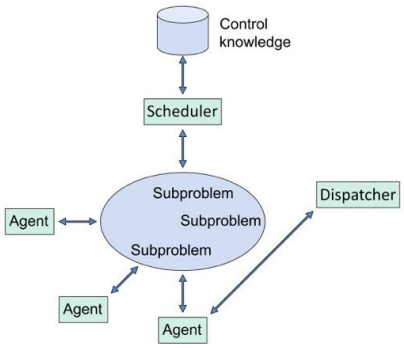

Figure 2. Extended Blackboard structure

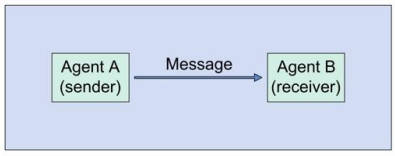

Figure 3. Transmission of a message principle

IV. DISTRIBUTED ARTIFICIAL INTELLIGENCE AND PROBLEM SOLVING

Many problems have a distributed nature, so they require a distributed solution. Specialized knowledge is often not available in an individual agent but may be distributed among different agents. As we have said in the previous section, in the interaction between agents it may be the case that various agents coordinate their tasks to reach a common goal. This aspect is treated in Distributed Artificial Intelligence (IAD), which we could define as [12]: "Distributed artificial intelligence is the study, construction and application of multi-agent systems, that is, systems in which several intelligent agents, interacting, pursue a set of objectives or perform a set of tasks".

Traditionally, two basic types of systems are distinguished: multiagent systems and distributed problem solving systems. While in multi-agent systems the emphasis is placed on coordination, in systems of distributed problem solving is the task of decomposition and synthesis of solutions. At present, there is no such differentiation and when talking about multi-agent systems we include both types.

V. MULTIAGENT SYSTEMS AND INTELLIGENT BUILDINGS

According to the characteristics that influence the condition of Intelligent Building: [13], the elements we must consider the following subsystems of agents:

- Green Building:
  - Control multiagent subsystem for energy saving.
  - Energy production multiagent subsystem.
  - Water consumption control multiagent subsystem
  - Gas emission control multiagent subsystem.
  - Wastewater emission control multiagent subsystem.
- Comfort:
  - Thermal Comfort control multiagent subsystem.
  - Control subsystem Ventilation and
  - Air Conditioning Control multiagent subsystem.
  - Control multiagent subsystem Lighting.
  - Control multiagent subsystem Access.
  - Noise control multiagent subsystem.
  - Lifts control multiagent subsystem.
- Efficiency for Work (own office buildings and services):
  - Signaling control multiagent subsystem.
  - Directory control multiagent subsystem.
  - Parking control multiagent subsystem.
- Cultural Elements:
  - Activities advertising facilitator multiagent subsystem.
- High Technology Image. It has been interpreted for many years as the only provision and / or criterion of an intelligent building. Element groups are:
  - Broadband Internet facilitator multiagent subsystem.
  - Multiagent Subsystem of Control of Electrical Services,.
  - Facilitator multiagent subsystem Automation of Offices.
  - Intelligent Control multiagent Subsystem.
  - Automation multiagent subsystem.

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- Multiagent subsystem for the control of Mobile Phone Coverage.
- Advanced Parking Facilities multiagent Subsystem.

- Security and Structure:
  - Fire protection multiagent subsystem.
  - Electrical safety multiagent subsystem.
  - Lift reliability multiagent subsystem.
  - Multiagent subsystem of public notices.
  - Exhaust plan multiagent subsystem.
  - Essential electrical energy multiagent subsystem.
  - Indoor air quality multiagent subsystem.
  - Security management multiagent subsystem.
  - Earthquake monitoring multiagent subsystem.
  - Structural monitoring multiagent subsystem.
  - Terrorist attack precaution multiagent subsystem.
- Building Management:
  - Security and Surveillance multiagent Subsystem.
- Healthy Buildings:
  - Drinking water control multiagent subsystem.
  - Elevator ventilation control multiagent subsystem.
  - Cleaning control multiagent subsystem.
  - Waste management control multiagent subsystem.
  - Pest control multiagent subsystem.
  - Pool filtration control multiagent subsystem.

The set of multiagent subsystems constitutes the multiagent system associated to the building. For all subsystems, we must have mechanisms that allow the integration of sensors, actuators and different automatic control systems.

The typologies of sensors are very varied, for example we have sensors to control accesses, temperature sensors, sensors of luminosity, security cameras, etc. Likewise, the types of actuators are very varied: door opening actuator, blind opening / closing actuator, air conditioning actuator, display screens, etc.

The multi-agent system associated to the intelligent building is composed of subsystems of agents in such a way that each subsystem acts autonomously, except when it needs information of any other, then by means of a slate structure or by passage of messages the request and reception takes place Information needed to act.

Basic conditions of a general nature must be taken into account: availability, security, and privacy. The three conditions must be propagated by all subsystems of agents for the purpose of their constant prevalence. In the physical installation, priority should be given to installations with structured wired cables, since wiring simplifies anti-intrusion measures in communications.

VI. CONCLUSION

Having established the concept of Intelligent Building, the complexity of its architectural design makes it convenient to have a structure of procedures that serves as a guide for its integrated design, this has been the objective of the article, multi-agent systems are an instrument of design and implementation. That allow to integrate the different control subsystems that characterize the Intelligent Buildings. The article provides a review of different approaches to multi-agent systems applied to building construction, the basic elements of multi-agent systems and the set of their systems to be considered in the early stages of the design of an Intelligent Building.

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